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APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTOR: ERICH STRASSER

TITLE: METHOD FOR THE FUNCTIONAL  
CONTROL OF A POSITION  
MEASURING SYSTEM AND  
POSITION MEASURING SYSTEM FOR  
EXECUTING THE METHOD

ATTORNEY: JOHN C. FREEMAN  
BRINKS HOFER GILSON & LIONE  
P.O. BOX 10395  
CHICAGO, ILLINOIS 60610  
(312) 321-4200

**METHOD FOR THE FUNCTIONAL CONTROL OF A POSITION  
MEASURING SYSTEM AND POSITION MEASURING SYSTEM FOR  
EXECUTING THE METHOD**

Applicant claims, under 35 U.S.C. § 119, the benefit of priority of the filing  
5 date of December 6, 2000 of a German patent application, copy attached, Serial  
Number 100 60 572.9, filed on the aforementioned date, the entire contents of which  
is incorporated herein by reference. Applicant also claims, under 35 U.S.C. § 119, the  
benefit of priority of the filing date of February 1, 2001 of a German patent  
application, copy attached, Serial Number 101 04 373.2, filed on the aforementioned  
10 date, the entire contents of which is incorporated herein by reference.

**BACKGROUND OF THE INVENTION**

**Field of the Invention**

The present invention relates to a method for the function control of a position  
measuring system with a scanning unit, which can be displaced with respect to a  
graduation, wherein the scanning unit has several detector elements and generates  
several scanning signals at an instantaneous relative position between the graduation  
and the scanning unit. The present invention also relates to a position measuring  
system for executing the method.

**Discussion of Related Art**

Position measuring systems in the form of angle and linear measuring devices  
are widely employed in the machine tool industry and in other manufacturing,  
manipulation and testing systems. A high degree of functional dependability increases  
in importance in all types of usage, since faulty operations can cause considerable

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damage. There have already been several suggestions for a solution by obtaining a timely error indication through monitoring tests and in this way to prevent resulting damage.

A method, as well as a device for monitoring the correctness of the detected measured position value is described in U.S. Patent No. 3,725,904, the entire contents of which are incorporated herein by reference, DE 28 25 842 C2 and corresponding U.S. Patent No. 4,311,987, the entire contents of which are incorporated herein by reference. Two scanning units, which are arranged offset from each other by a predetermined distance, are provided for scanning a coding, or a graduation. The two measured position values of the two scanning units are compared to each other and a position difference is formed. This measured difference is compared with a nominal difference, predetermined by the geometric arrangement of the scanning units, and an error signal is issued as a function of the result of the comparison.

This step has the disadvantage that a redundant scanning unit is required, which increases the structural size and the output for structural elements.

Only one scanning unit is required with the position measuring device in accordance with DE 40 09 749 A1. For performing the test procedure, the scanning unit is displaced over a distance fixed by stops, and the distance measured in this way is compared with the distance defined by the stops. An error signal is generated when there is a deviation.

The disadvantage of this step lies in the provision of mechanical stops and the provision of an additional drive mechanism, which considerably increase the structural size.

## OBJECTS AND SUMMARY OF THE INVENTION

It is therefore an object of the present invention to disclose a method for the functional control of a position measuring system which can be simply performed and which does not, or only negligibly, increase the structural size of the position measuring device.

This object is attained by a method for the functional control of a position measuring system that includes placing a scanning unit at a position with respect to a graduation, generating a first scanning signal and a second scanning signal during the displacing, forming a first measured position value, P1, in accordance with a first linkage rule that involves the first scanning signal and the second scanning signal and

10 forming a second measured position value, P2, in accordance with a second linkage rule that involves the first scanning signal and the second scanning signal, wherein the first linkage rule differs from the second linkage rule. Comparing the first measured position value, P1, with the second measured position value, P2, and generating an error signal as a result of the comparing.

It is a further object of the present invention to disclose a position measuring system for executing the method.

This object is attained by a position measuring system that includes a graduation and a scanning unit that is positioned with respect to the graduation, 20 wherein the scanning unit includes a detector system that generates a first scanning signal and a second scanning signal at an instantaneous relative position between the graduation and the scanning unit. An evaluation unit receives the scanning signal and forms a first measured position value, P1, based on the first scanning signal and the second scanning signal in accordance with a first linkage rule and a second measured

position value, P2, based on the first scanning signal and the second scanning signal in accordance with a second linkage rule, wherein the first linkage rule differs from the second linkage rule. A comparator device receives the first and second measured position values, P1, P2, so as to generate an error signal as a function of the 5 comparator comparing the first and second measured position values, P1, P2.

It is possible by the method in accordance with the present invention to detect in a simple way a malfunction of the detector elements of the scanning unit, as well as malfunctions of the electrical components in the individual scanning channels, in particular the amplifier and the trigger.

10 Further advantages, as well as details of the present invention, ensue from the following description of a preferred embodiment represented in the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a shows a first exemplary embodiment of a position measuring system in a first control state according to the present invention;

15 FIG. 1b shows the position measuring system in FIG. 1a in a second control state;

FIG. 2a shows a second embodiment of a position measuring system in a first control state according to the present invention; and

20 FIG. 2b shows the further position measuring system of FIG. 2a in a second control state.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first exemplary embodiment of the present invention is represented in FIGS. 1a and 1b. The position measuring system includes a photoelectrically scannable graduation 1, which is illuminated by light generated by a light source 2. The graduation 1 is scanned by a scanning unit 3 that is displaced relative to the graduation 1. During its displacement, the scanning unit 3 generates position-dependent electrical scanning signals A, B, C, D. The graduation 1 has an incremental, i.e. a periodic, marking so that the light emitted by the light source 2 impinges, periodically modulated, on a detector system that includes detector elements 3A, 3B, 3C, 3D of the scanning unit 3, which are arranged offset with respect to each other, and analog sinusoidal scanning signals  $A = a + \sin\alpha$ ,  $B = a - \sin\alpha$ ,  $C = a + \cos\alpha$ ,  $D = a - \cos\alpha$  are generated, wherein a is a d.c. component and  $\alpha$  is an angular value that ranges from  $0^\circ$  to  $360^\circ$  and is proportional to the instantaneous position within a graduation period of the incremental graduation. The periodic scanning signals A, B, C, D are each offset by  $90^\circ$  with respect to each other in a known manner, with the phase location being  $A = 0^\circ$ ,  $B = 180^\circ$ ,  $C = 90^\circ$ ,  $D = 270^\circ$ . The periodic scanning signals A, B, C and D are generated at an instantaneous relative position between the graduation 1 and the scanning unit 3.

To eliminate the d.c. component a, the counter-phased scanning signals A, B and C, D are combined in accordance with linkage rules described below. In particular, scanning signals A, B and C, D are each differentially connected, for which purpose differential amplifiers are provided, at whose output lie the differential resultant signals  $E = A - B = 2\sin\alpha$ , and  $F = C - D = 2\cos\alpha$ . These differential signals

E and F are supplied to an evaluation unit in the form of an interpolation unit 6 which, from the phase position of the differential signals E, F, forms an absolute measured position value P1 within a period of the periodic differential signals E, F in a known manner and stores it in a comparator device 7. This operation of the position measuring system is represented in FIG. 1.

The absolute measured position value P1 is calculated in the interpolation unit 6, for example in accordance with a linkage rule defined by the equation  $P1 = \arctan E/F$ . However, interpolation can also take place by reading out tabular values.

A switch-over device 8 is provided for the function control of the position measuring system, which applies the scanning signals A, B, C, D to the interpolation unit 6 in a different linkage. This state is represented in FIG. 1b. The scanning signals A, B, C, D are applied to different inputs of the differential amplifiers 4, 5 by the switches 81, 82, 83, 84, so that the differential resultant signal  $F = C - D$  is formed by the differential amplifier 4, and the differential resultant signal  $K = B - A$  by the differential amplifier 5. The interpolation unit 6 forms a second absolute measured position value P2 within a period of the periodic differential signals F, K in accordance with a different linkage rule defined by the equation  $P2 = \arctan F/K$ . Thus, this second measured position value P2 is a synthetically generated measured position value P2, so to speak, which is generated in accordance with a linkage rule of the scanning signals A, B, C, D, which differs from the actual measuring operation in accordance with FIG. 1a. This measured position value P2 is also supplied to the comparator device 7 and is stored there.

Both measured position values P1 and P2 are compared with each other in the comparator device 7 and are changed for a nominal distance. Under correct operating

conditions, in the explained example  $P_2 = P_1 - T/4$ , with  $T$  = the signal period of the differential signals E, F, K. If, for example, a signal period ( $360^\circ$ ) is divided into 256 equal parts (interpolation factor = 256), the comparison  $P_2 = P_1 - 64$  must result if all components which contribute to the generation of the scanning signals A, B, C, D, as well as E, F, K, operate error-free. If the result of this comparison does not lie within a predetermined tolerance range, an error signal R is issued.

The advantage of the present invention lies in that it is possible to perform a function control in a stopped state, i.e. without a relative movement between the graduation 1 and the scanning unit 3. All components of the individual scanning channels for generating the individual scanning signals A, B, C, D, E, F, K, as well as the interpolation unit 6, are included in the function control.

A second exemplary embodiment is represented in FIGS. 2a and 2b. FIG. 2a shows the position measuring system during normal measuring operations, the same as in accordance with FIG. 1a. The switches 81, 82 are used to supply the scanning signals A and D in a second state to the first differential amplifier 4, so that the differential signal  $A - D = G$  lies at its output, and to supply the scanning signals C and A to the second differential amplifier 5, so that the differential signal  $C - A = H$  lies at its output. In this state the interpolation unit 6 forms a second absolute measured position value  $P_2'$  within a period of the periodic differential signals G and H in accordance with the equation  $P_2' = \arctan G/H$ . This second measured position value is the synthetically generated measured position value  $P_2'$ , which is generated in accordance with a linkage rule of the scanning signals A, B, C, D which differs from the actual measuring operation.

Both measured position values P1 and P2' are compared with each other in the comparator device 7 and are tested for the nominal distance. In this second example, under correct operating conditions,  $P2' = P1 - T/8$ , with T = the signal period of the differential signals G and H. If, for example, a signal period ( $360^\circ$ ) is divided into 256 equal parts, the comparison  $P2' = P1 - 32$  must result, if all components which contribute to the generation of the scanning signals A, B, C, D, as well as G and H, operate error-free.

The process of function control preferably takes place during the start-up of the position measuring device, however, it can also take place during the measuring operation, namely during time periods in which no measured position values for positioning a machine element is requested by an external electronic sequential device. The function control in accordance with the present invention preferably takes place within the position measuring system.

With all exemplary embodiments it is possible to use digitized scanning signals for the function control in place of analog scanning signals A to H.

The switch-over device 8 is represented with discrete switches 81 to 84 for explaining the functioning of the invention. In actual operation, this switch-over device 8 in the form of software would be a component of the interpolation unit 6.

The invention is not limited to the photoelectrical position measuring device described, it can also be employed in connection with magnetic, inductive, and well as capacitive, linear, as well as angular, measuring systems. The invention has only been explained by the scanning of a graduation 1. Of course, it can also be employed with multi-track absolute position measuring systems, wherein each track represents a

periodic graduation, and the scanning units of the individual graduation tracks are tested in accordance with the present invention.

The foregoing description is provided to illustrate the invention, and is not to be construed as a limitation. Numerous additions, substitutions and other changes can  
5 be made to the invention without departing from its scope as set forth in the appended claims.